

Urinary System

Kidneys

def. compound tubular gland responsible for:

1. Excretion of urine & its waste products. (urea & uric A)
2. Regulate fluid & electrolyte balance + reabsorption of H_2O .
3. production of: renin, erythropoietin & medullipin I

Formed of:

I Stroma:

- a. capsule: dense fibrous c.t. Thin, covered & adipose c.t.
- b. renal interstitium: contains fibroblasts, macrophages + Interstitial cells
 & secrete **Medullipin I** converted in the liver into **Medullipin II** (potent hypotens)

II. Parenchyma:

A. Cortex

* red (rich in bl. vs.) & granular (renal corpuscles) * Formed of:

Malpighian renal corpuscles, convoluted tubules, medullary rays + peritubular vs.

* It includes:

1. Cortex proper: under the capsule.
2. Columns of Bertini: between the medullary pyramids (on either side)
3. Cortical labyrinth: surround the medullary rays = nephrons that drain into the same collecting tubule

B. Medulla:

* grey * 6-12 medullary pyramids. The base of the pyramid points to the Cortex
 & its apex (renal papilla) points to the renal pelvis. It is perforated by
 20 openings of collecting ducts = ducts of Bellini.

The apex projects into a minor calyx. 3-4 minor calyces → a major calyx
 → empty in renal pelvis [the upper expanded end of the ureter].

* Each pyramid shows radial striations [Collecting tubules, ducts of Bellini
 vasa rectae + straight tubules of loop of Henle.] = Medullary rays

* The medullary rays extend into the cortex.

• **Renal Lobe** = medullary pyramid + overlying cortical arch +
 Columns of Bertini on either side of the pyramid.

• **Renal Lobule** = Each medullary ray = collecting duct & all nephrons
 that it drains. Demarcated by interlobular arteries.

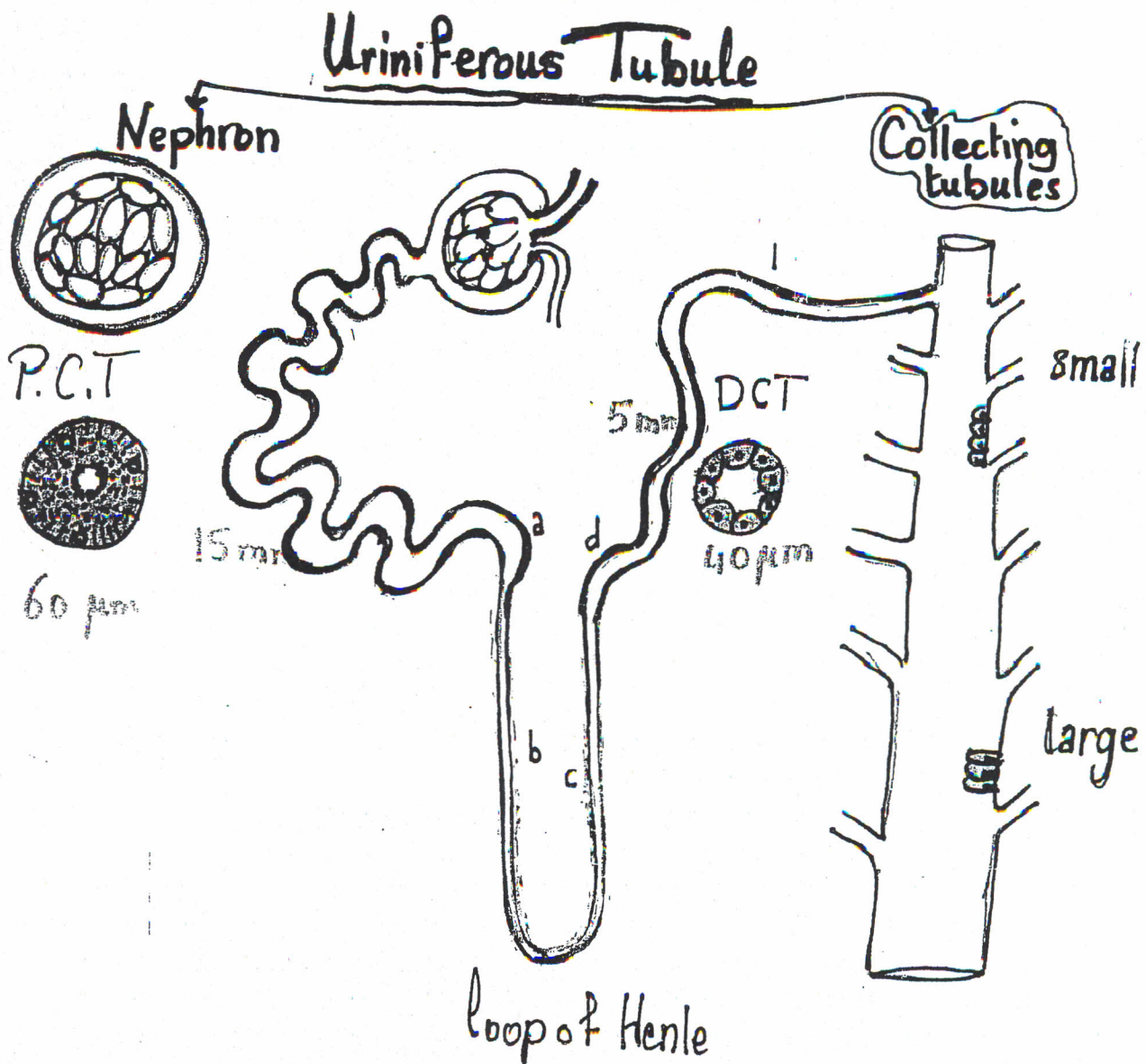
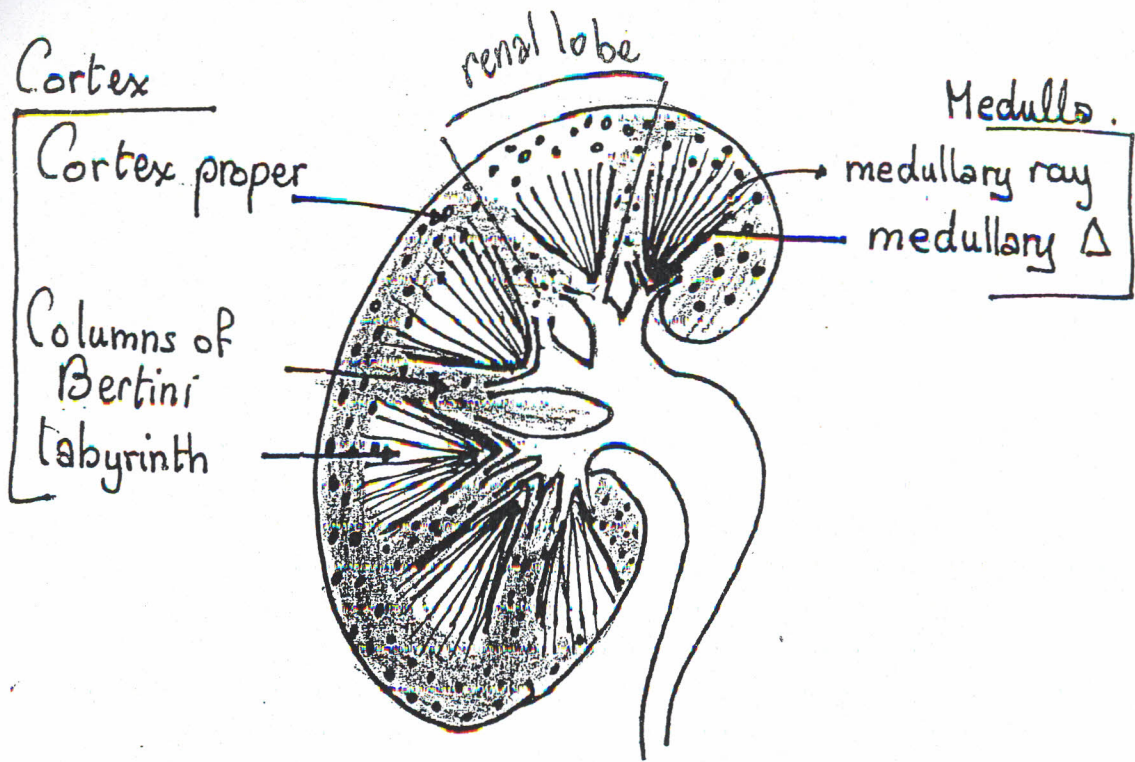
The Uriniferous Tubule

Nephron

Collecting duct

VISIT...

LANZAROTE
Caliente.COM



A. The Nephron.

- The structural & functional unit of the kidney.
- each kidney contains 1-1.4 million nephrons.
- Each nephron is formed of
 - ↳ Malpighian renal corpuscle
 - ↳ proximal & distal convoluted tubules.
 - ↳ loop of Henle.
- Classified into:
 - a. Cortical nephrons: e' short loop of Henle.
 - b. Juxta-medullary nephrons: e' long loop of Henle.

1. Malpighian Renal Corpuscle:

- about 200 μm in diameter. Formed by invagination of the spherical blind end by a tuft of capillaries [Glomerulus] $\rightarrow$ Bowman's capsule.
- Has 2 poles:
 - a. Vascular pole: where an afferent arteriole enters & efferent arteriole leaves.
 - b. Urinary pole: continuous e' the proximal convoluted tubule.
- Each renal corpuscle is formed of glomerulus & Bowman's capsule.

Glomerulus

- At the vascular pole, afferent arteriole [carrying unfiltered blood] divides repeatedly $\rightarrow$ capillary tuft $\rightarrow$ drain into efferent arteriole [carry filtered blood]. - The afferent arteriole have larger diameter & thicker media than the efferent arteriole [to create high glomerular press. to produce large amount of glomerular filtrate].

L.M. - lined e' fenestrated endothelium

- the basement membrane is: thick & continuous. (PAS+ve).

E.M. - The endothelium has pores (100 nm in diameter) Not covered by diaphragms.

- The Glomerular Basement membrane (GBM) =

- Formed of 3 layers:
 - a. lamina rara [lucida] externa = out. electron lucent
 - b. lamina rara [lucida] interna = inner " " "
 - c. lamina densa = central electron dense L.

Bowman's Capsule

- A double wall cup-shaped epith. capsule. Formed of 2 continuous layers:
- Formed of 2 layers:
 - a. Outer parietal layer: lined e' simple squamous epith.
 - b. Inner Visceral layer: Invests the glomerular capillaries, formed of, modified squamous cells called podocytes.
- The visceral & parietal layers are separated by capsular space.

Podocyte :

def. = modified squamous cells lining the visceral layer of Bowman's capsule.

E.M. = stellate shaped cells separated from the glomerular capillaries by subpodocytic space. Have cell body from w major processes arise. From major processes, minor processes arise & are implanted at intervals on the glomerular capillaries. The minor processes of adjacent podocytes interdigitate leaving gaps bet. them. The gaps are called filtration slits, covered by semipermeable memb. called [filtration slit diaphragms].

The filtration slit diaphragms = trans memb. protein nephrin
→ Zipper - like sheet. It has central dense core & pores on both sides.

The cytoplasm contains many ribosomes, r.ER, mit., Golgi complex & actin microfilaments (podocytes are contractile)

Functions :

1. Involved in formation of the blood renal barrier.
2. renewal of the basement membrane of glomerular capillaries.

The Blood Renal Barrier : Glomerular Filtration Barrier

It is the barrier w separates blood in the glomerular capillaries from the glomerular filtrate in the capsular space & through w filtration of blood occurs. Formed of :

① Fenestrated endothelium of the glom. capillaries :

depends on molecular weight & size. It allows passage of molecules smaller than bl. cells & platelets e.g. plasma proteins

② Glomerular basement memb. [GBM]

- the most effective barrier. the only continuous layer. depends on :

a. Molecular weight :

- prevent passage of large molecules ($> 160,000$ Dalton) e.g. plasma ptns
- allows " " small " e.g. sugars & a.a.s.

b. Molecular charges :

The -ve charges on both laminae rarae prevent passage of -ve charged molecules e.g. albumin (although its MW is 69,000 Dalton)

③ Filtration Slit diaphragms :

- Cover the spits bet. the feet of podocytes & depends on :

a. Molecular weight : allows passage of molecules e' MW $< 40,000$ D

b. Molecular charges : It is -vely charged so, prevent passage of -vely charged molecules.

The Mesangial Cells:

-5-

- Shape:** small stellate cells. Have small dark nuclei. Basophilic cytoplasm rich in lysosomes.
- Types & sites:**
 - (a) Intraglomerular: bet. the glomerular capillaries in the renal corpuscle
 - (b) Extraglomerular: at the vascular pole.
- Functions:**
 - Supportive function:** secrete collagen, chondroitin sulphate, fibronectin & mesangial matrix.
 - renewal of GBM.**
 - Contractile function:** so, regulate bl. flow in glom. caps. in response to vaso-active subs.
 - Phagocytic "** : extend processes bet. endoth. cells of glom. caps to phagocytose debris or residues during renewal of GBM
 - Extra glom. mesangial cells:** form part of Juxtaglom. apparatus.

	<u>[2] Proximal Convolved tubule</u>	<u>[3] Distal Convolved tubule</u>
Size	- longer (15 mm). - more convoluted. - larger diameter (60 μm). - narrow lumen.	- shorter (5 mm) - less convoluted. - small diameter (40 μm) - wider lumen.
Site	- starts at urinary pole of renal corp - ends at descending limb of loop of Henle	- start at end of ascending limb of loop of Henle - ends at collecting duct.
L.M. of lining epith.	- 3-4 cells - high cuboidal (Δ) cells * non-clear boundaries. - Apical brush border. • basal acidophilic striations. - deeply acidophilic & granular cytoplasm - rounded & basal nuclei	- 5-8 cells (up to 20 in macula densa) - low cubical cells. * clear boundaries. - less brush border. • Less basal striations. - Less acidophilic & less granular. - rounded & central nuclei.
E.M.	- apical long microvilli $\rightarrow$ brush border * extensive interdigitations of lat. membrane $\rightarrow$ non-clear boundaries • Basal infoldings & associated parallel mitochondria $\rightarrow$ basal striations - numerous mitochondria $\rightarrow$ more acidophilic	- Fewer & shorter microvilli $\rightarrow$ no brush border * Less interdigitations $\rightarrow$ clear boundaries • present but less $\rightarrow$ less - less mitochondria $\rightarrow$ less acidophilic
Functions	- reabsorption of glucose & a.a. - reabsorption of Na^+, Cl^-, K^+ & H_2O.	- reabsorption of Na^+ & H_2O under control of aldosterone & ADH - excretion of H_2 & NH_3

In Diabetic nephropathy & Glomerulonephritis: the glomeruli are affected & the barrier is disrupted $\rightarrow$ albuminuria or hematuria

4. Loop of Henle

- U-shaped tube connects the PCT & DCT.
- present in medullary rays in cortex & medulla.
- Cortical nephrons have short loop of Henle while Juxtamedullary " " long " " " " " "
- Formed of:
 - Thick descending part: similar to PCT, lined e' cuboidal epith.
 - thin " limb: lined e' simple squamous epith.
 - " ascending " " " " " "
 - thick " part: similar to DCT, lined e' s. cubical epith.

Functions:

Concⁿ of Urine (Hypertonic urine) & conserving H₂O.

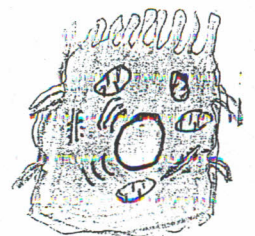
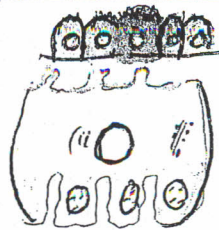
B. The Collecting Tubules

- The excretory part of the uriniferous tubules.
- a group of nephrons drain into ^{arched} collecting tubule (lined e' s. cuboidal)
- Each 6-8 small collecting tubules drain into straight collecting duct = duct of Bellini (lined e' s. col. epith.) w open into the tips of the medullary pyramids

Function: Concⁿ of urine under control of ADH

The collecting tubules & ducts have 2 types of cells:

	Principal cells	Intercalated cells
No	- numerous.	- Few
Stain Intensity	- Weak (pale)	- dark
EM:		
• Organelles	- Few	- Abundant.
• mitochondria	- Few, small, spherical	- more
• Basal infoldings	- numerous (ion transporting)	- absent
• microvilli	- short & scanty.	- more
• lat. interdigitat ^{ns}	- Absent (clear boundaries)	- More (non-clear boundaries)



Diabetes Insipidus: insufficient productⁿ of ADH →
 ↓ reabsorption of H₂O from the collecting tubules →
 hypotonic pale ~~urinated~~ urine but normal bl. sugar.

Juxta. Glomerular Apparatus

-7-

def.: complex structure at the vascular pole of some renal corpuscles
formed of:

1. Juxta. glomerular cells: (J.G. cells)

modified smooth muscles of the tunica media of the afferent (sometimes efferent) arteriole. Shows the following changes:

- 1. nuclei become rounded. 2. Cytoplasm have PAS+ve secretory granules (renin)

Function: secrete renin enz.

2. Macula densa:

= The part of the DCT that fits bet. the afferent & efferent arterioles at the vascular pole. It shows the following changes:

- Cells ↑ in No. & height (become columnar) & their nuclei become apical, dark & closely packed so appear as dark spot by the L.M.
- G.A. becomes infranuclear (basal).
- The basement memb. is absent so, cells become in contact w/ J.G. cells.

Function: Osmoreceptors. it monitors the level of Na^+ in the DCT.

3. Extra glomerular Mesangial cells:

[Lacis cells, Polkissen cells in Polar Cushion]

pale cells in between the afferent, efferent arterioles & macula densa.

Function: supportive & may transmit signals from macula densa to glom. cap

• Functions of J. G. Apparatus:

regulates bl. press. through Renin. Angiotensin - aldosterone system:

1. drop of bl. press. or vol. (as in hemorrhage) → ↓↓ vol. of glom. filtrate
2. ↓↓ Na^+ & Cl^- ion concⁿ in DCT.

3. Macula densa monitors the changes & stimulate J.G.C → renin

4. Angiotensinogen $\xrightarrow{\text{renin}}$ Angiotensin I $\xrightarrow{\text{ACE}}$ Angiotensin II
(in bl. & formed in liver)

ACE = angiotensin converting enz. secreted by endoth. of lung caps

5. Angiotensin II raises bl. press. by:

vasoconstriction

stimulate Adr. cortex

stim. pit. gl
↓ release

Aldosterone

ADH

↑↑ Na^+ reabsorption in DCT

↑↑ H_2O reabsorptⁿ in collecting tubules

Return of bl. press. $\xrightarrow{\text{-ve feedback}}$ inhibits secretion of renin by J.G. A.

Blood Supply of Kidney

Renal artery: at the hilum gives:

Interlobar arteries: between the pyramids. At the cortico-medullary junction it gives Arcuate arteries at the base of the pyramids.

It gives Interlobular arteries: that terminate as capsular capillaries

Interlobular arterioles: give many afferent arterioles → glomerular capillaries → efferent arterioles that give peritubular capillaries (supply the PCT & DCT) → peritubular venules → interlobular vein → arcuate vein → inter-lobar vein → renal vein at the hilum.

• Juxta-medullary efferent arterioles → straight arteriolae rectae w extend in the medullary pyramids → venulae rectae w drain into interlobular or arcuate vein → renal v.

∴ Vasa rectae =

Urinary Passages

minor & major calyces → renal pelvis → Ureter → Urinary bl. → Urethra.

Ureter

It's wall is formed of:

I. Mucosa:

shows longitudinal folds
→ stellate shape lumen.

- = (a) transitional epith
- (b) underlying c.t. corium

Both, the folds & the epith. allow distention of the ureter to allow passage of small stones in urine

II. Musculosa:

The upper $\frac{2}{3}$: inner long. & outer circ. The lower $\frac{1}{3}$ has additional outer long. L.

Their contraction → peristaltic wave so propel urine → Ur. bladder.

III. Adventitia:

fibro-elastic c.t. rich in bl. vs. nerves L. vs.

Urinary bladder

It's wall is formed of:

I. Mucosa:

(a) Transitional epithelium:

In empty bladder 5-6 layers & superficial cells are cuboidal & bulge in the lumen (dome or umbrella cells)

In full bladder: 3-4 layers & superficial cells become squamous.

(b) Underlying c.t. corium.

II. Musculosa:

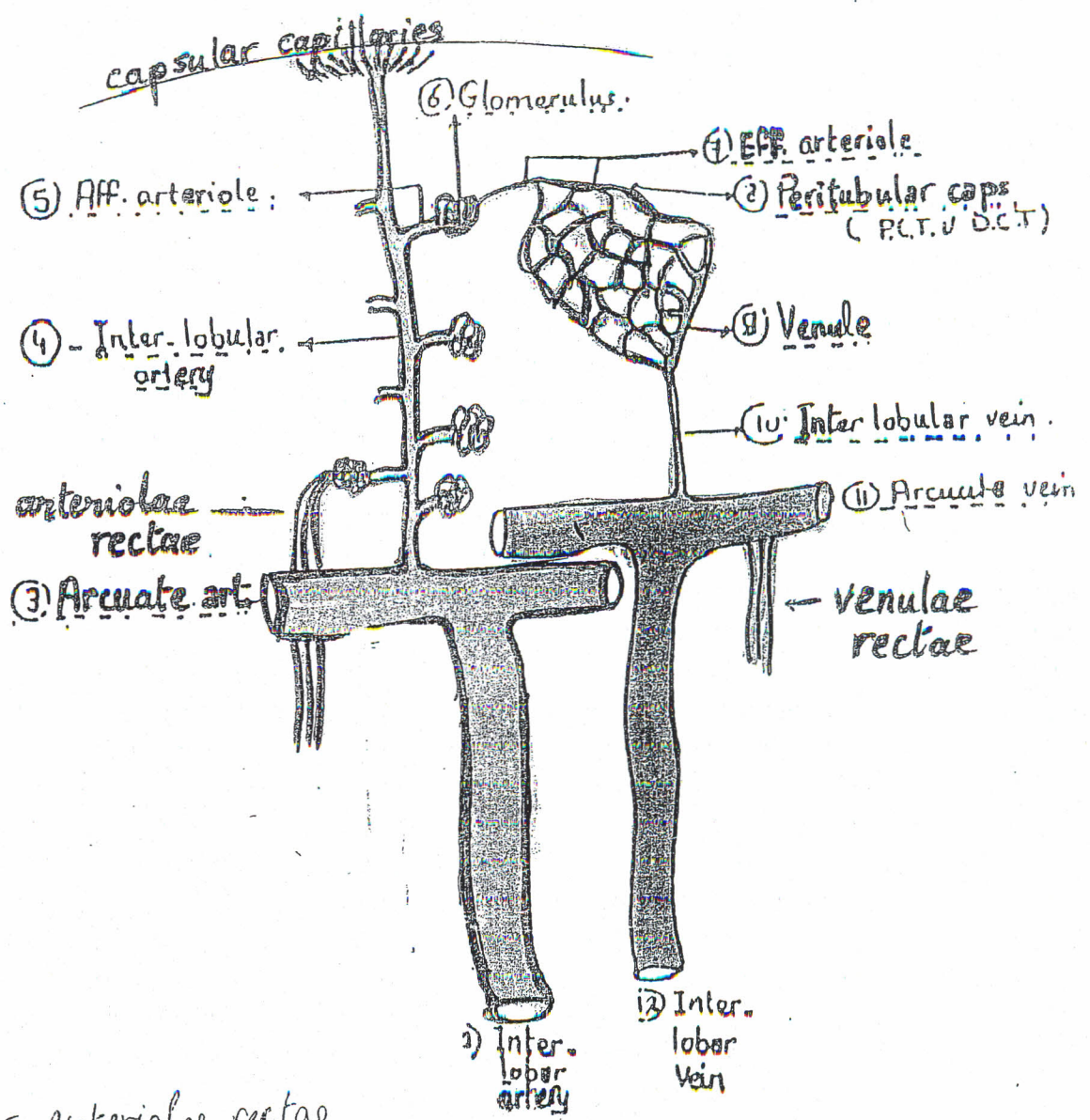
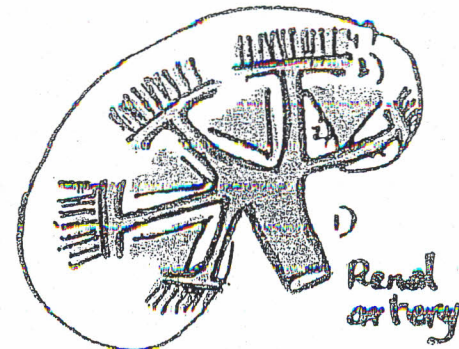
formed of inner & outer long. & middle circular sm. ms.

At the neck of the bladder, the inn. long. becomes circ. to form the internal urethral sphincter.

III. Adventitia:

fibro-elastic c.t. except the sup. part, covered e' serosa

Blood Supply of the Kidney



Cortex

Medulla

Vasa rectae = arteriolae rectae + Venulae

Uro epith. = Transitional epith. ∴ 3 layers :

1. Basal layer : 1 layer of cuboidal cell resting on non clear b.m.
2. Intermediate L. : several layers of polyhedral cells.
3. Superficial "umbrella cells" L. : dome shaped cells, may be binucleated

Urethra

♂ Urethra :

20 cm long tube that carries both urine & semen. Divided into

1. Prostatic Urethra :

- passes through the prostate
- lined e' transitional epith.
- surrounded by the int. urethral sphincter

2. Membranous Urethra :

- passes through the urogenital diaphragm.
- lined e' pseudo-stratified col. epith. or st. col.
- surrounded by skeletal ms. of pelvis → ext. sphincter.

3. Penile Urethra :

- passes in corpus spongiosum of the penis.
- lined e' stratified columnar epith. w changes into st. sq. at it's terminal part (fossa navicularis)
- Glands of Littre open into it.

♀ Urethra :

a short tube lined e' transitional, ps. st. col or st. col. then st. sq. at it terminal end.

Urinary Incontinence = loss of voluntary control on the ext. urethral sphincter ms. esp. in older women